DACA42-02-C-0001

LOGANEnergy Corp.

Airman Dormitory Building #4650 PEM Demonstration Program
Barksdale Air Force Base,
Bossier City, Louisiana
Final Report

Proton Exchange Membrane (PEM) Fuel Cell Demonstration
Of Domestically Produced PEM Fuel Cells in Military Facilities

US Army Corps of Engineers
Engineer Research and Development Center
Construction Engineering Research Laboratory
Broad Agency Announcement CERL-BAA-FY01

Barksdale Air Force Base
Bossier City, Louisiana

October 5, 2004

Executive Summary

In October 2001, LOGANEnergy Corporation received a contract award from the US Army Corps of Engineers, Construction Engineering Research Lab to test and evaluate Proton Exchange Membrane (PEM) Fuel Cells at several DOD sites. Barksdale Air Force Base in Bossier City, Louisiana, Headquarters of the 8th Air Force, is one of the sites awarded to LOGAN. The main purpose of this program was to demonstrate the feasibility of obtaining a minimum of 90% availability over a one year period using a residential PEM fuel cell. This is the final report on the operation of the PEM fuel cell.

Building #4650, an airman's dormitory building was chosen for the demonstration site. It hosts a five kilowatt, 120 volt ac, SU-1 PEM technology demonstration fuel cell manufactured by Plug Power Corporation, Latham, NY. The unit operates continuously in a base load, grid parallel configuration at power setpoint of 2.5kW. The unit is instrumented with an external wattmeter and a gas flow meter. A phone line is connected to the power plant communication's modem to call-out with alarms or events requiring service and attention.

The initial start-up of this fuel cell occurred on December 13, 2002 and the final shutdown was on March 5, 2004. During this period the fuel cell operated for 3,200 hours or 42% of the total hours in the demonstration period. This is significantly below the 90% availability targeted for this program.

The Point of Contact for this project is Nathan Cost, Barksdale Air Force Base Energy Manager, (318) 456-3706.

The total estimated energy cost increase to Barksdale Air Force Base as a result in participating in this demonstration project is $1677.34.

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Proposal – Proton Exchange Membrane (PEM) Fuel Cell Demonstration of Domestically Produced Residential PEM Fuel Cells in Military Facilities

1.0 Descriptive Title

Airman Dormitory Building 4650 PEM Demonstration Program, Barksdale Air Force Base, Bossier City, Louisiana

2.0 Name, Address and Related Company Information

LOGANEnergy Corporation
1080 Holcomb Bridge Road
BLDG 100- 175
Roswell, GA 30076

(770) 650- 6388

Data Universal Numbering System (DUNS) Number: 01-562-6211
Commercial and Government Entity (CAGE) Code: 09QC3
Taxpayer Identification Number (TIN): 58-2292769

LOGANEnergy Corporation is a private Fuel Cell Energy Services company founded in 1994. LOGAN specializes in planning, developing, and maintaining fuel cell projects. In addition, the company works closely with manufacturers to implement their product commercialization strategies. Over the past decade, LOGAN has analyzed hundreds of fuel cell applications. The company has acquired technical skills and expertise by designing, installing and operating over 30 commercial and small-scale fuel cell projects totaling over 7 megawatts of power. These services have been provided to the Department of Defense, fuel cell manufacturers, utilities, and other commercial customers. Presently, LOGAN supports 30 PAFC and PEM fuel cell projects at 21 locations in 12 states, and has agreements to install 22 new projects in the US and the UK over the next 18 months.

3.0 Production Capability of the Manufacturer

Plug Power manufactures a line of PEM fuel cell products at its production facility in Latham, NY. This facility, which opened in February 2000, is comprised of 50,000 square feet of dedicated production and production test facilities. The facility produces three lines of PEM products including the 5kW GenSys5C natural gas unit, the GenSys5P LP Gas unit, and the GenCor 5kW standby power system. The current facility has the capability of manufacturing 10,000 units annually.

Plug will support this project by providing remote monitoring, telephonic field support, overnight parts supply, and customer support. These services are intended to enhance the reliability and performance of the unit and achieve the highest possible customer satisfaction. Scott Wilshire is the Plug Power point of contact for this project. His phone number is 518.782.7700 ex1338, and his email address is scott_wilshire@plugpower.com.

4.0 Principal Investigator(s)

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6.0 Past Relevant Performance Information

a) Contract: PC25 Fuel Cell Service and Maintenance Contract #X1237022

Ms. Stephanie Chapman
Merck & Company
Bldg 53 Northside
Linden Ave. Gate
Linden, NJ 07036
(732) 594-1686

Contract: Four-year PC25 PM Services Maintenance Agreement.
In November 2002 Merck & Company issued a four-year contract to LOGAN to provide fuel cell service, maintenance and operational support for one PC25C fuel cell installed at their Rahway, NJ plant. During the contract period the power plant has operated at 94% availability. LOGAN performs the quarterly and annual service prescribed by the UTC, and performs other maintenance as required. The periods of unavailability are chiefly due to persistent inverter problems that seem to be endemic to the Toshiba power conditioning balance of the system. Field modifications and operating adjustments have largely cured the problem. Quarterly service events take 10 hours to complete with the unit under load, and the annual event takes approximately 35 hours with the unit shut down.

b) Contract: Plug Power Service and Maintenance Agreement to support one 5kWe GenSys 5C and one 5kWe GenSys 5P PEM power plant at NAS Patuxant River, MD.

Plug Power

Mr. Scott Wilshire.
968 Albany Shaker Rd.
Latham, NY 12110
(518) 782-7700 ex 1338

LOGAN performed the start-up of both units after Southern Maryland Electric Cooperative completed most of the installation work. The units are located at residential sites at Patuxant River Naval Air Station, VA and operate in standard gird connected/grid independent configurations. Both operate at 4.5kWe and have maintained 98% availability. The units, S/Ns 241 and 242 are two of the very latest GenSys models to reach the field. S/N 242 is Plug Power's first LPG fueled system to go into the field. Both have set a new level of performance expectations for this product, and are indicative of the success of the various test and evaluation programs that have been conducted over the past two years.

c) Contract: A Partners LLC Commercial Fuel Cell Project Design, Installation and 5-year service and maintenance agreement.
Contract # A Partners LLC, 12/31/01

Mr. Ron Allison
A Partners LLC
1171 Fulton Mall
Fresno, CA 93721
(559) 233-3262

On April 20, 2004 LOGAN completed the installation of a 600kWe PC25C CHP fuel cell installation in Fresno, CA. The system operating configurations allow for both grid parallel and grid independent energy service. The grid independent system is integrated with a multi unit load sharing electronics package and static switch, which initial development was funded by ERDC CERL in 1999. This is the fifth fuel cell installation that uses the MULS System. The thermal recovery package in the project includes a 100-ton chiller that captures 210 degree F waste heat supplied by the three fuel cells to cool the first three floors of the host facility. The fuel cells also provide low-grade waste heat at 140 degrees F that furnishes thermal energy to 98 water source heat pumps located throughout the 12-story building during the winter months.

7.0 Host Facility Information

Barksdale Air Force Base, is located in Bossier city, Louisiana, near Shreveport in the northwestern corner of the State. Barksdale is headquarters for the 8th Air Force and 2d Bomb Wing. It sits on 22,000 acres of land, 20,000 of which is used for recreation and as a game reserve. In 1933, it was the largest airfield in the world, known then as Barksdale Field. Its primary aircraft today are the B-52 Stratofortress and A-10 Warthog.

The ASHRAE design temperatures for Barksdale are 99 and 22 F. The site averages 2,243 heating degree days and 2,487 cooling degree days. The cooling season extends almost year round. The elevation is approximately 167 feet.

American Power Company and Center Point/ Arkla Gas Company are the electricity and natural gas providers for the base respectively.

8.0 Fuel Cell Installation

The site chosen for installation is Building #4650 located in the base residential quad and serves as an Airman's dormitory. The fuel cell pad site is just outside the dorm's mechanical room providing easy access to utility power, water and natural gas service. In preparation for the installation, LOGAN processed a digging permit issued by the Civil Engineering department at Barksdale AFB. No other permits were required at this site.

The installation tasks were completed on November 20, 2002, requiring a total of 170 man-hours through completion and commissioning. The initial start attempt occurred on November 22, 2002, but was not successful because the unit's batteries depleted after multiple start cycles. Additional attempts to start the unit followed over the next two weeks with several issues hampering progress including, a week of inclement weather, troubleshooting a failed thermal couple (TC), repairing a failed weld in the reformer Proxair section, a failed battery charger, and troubleshooting a stuck valve on the humidifier.

Figure 1 - PEM Fuel Cell on Pad

The chief reasons for the cost differential between the estimated and the actual project costs are due to the extra time repairing "out of the box" product deficiencies described above. In retrospect, these issues were more time consuming than anticipated because the PEM unit was a "reconditioned" model that had prior field service. Plug Power supplied the fuel cell for Barksdale after Avista's product, originally awarded for this site, failed to meet the FY '01 CERL BAA product

specifications. Since the funding level approved for the Avista product was insufficient to purchase a new Plug unit, the only available option was to accept a reconditioned one.

The first start and acceptance certification took place on Dec 13, 2002; at which time the unit ran continuously for 8 hours. Appendix 2 documents the commissioning tasks leading to the initial start.

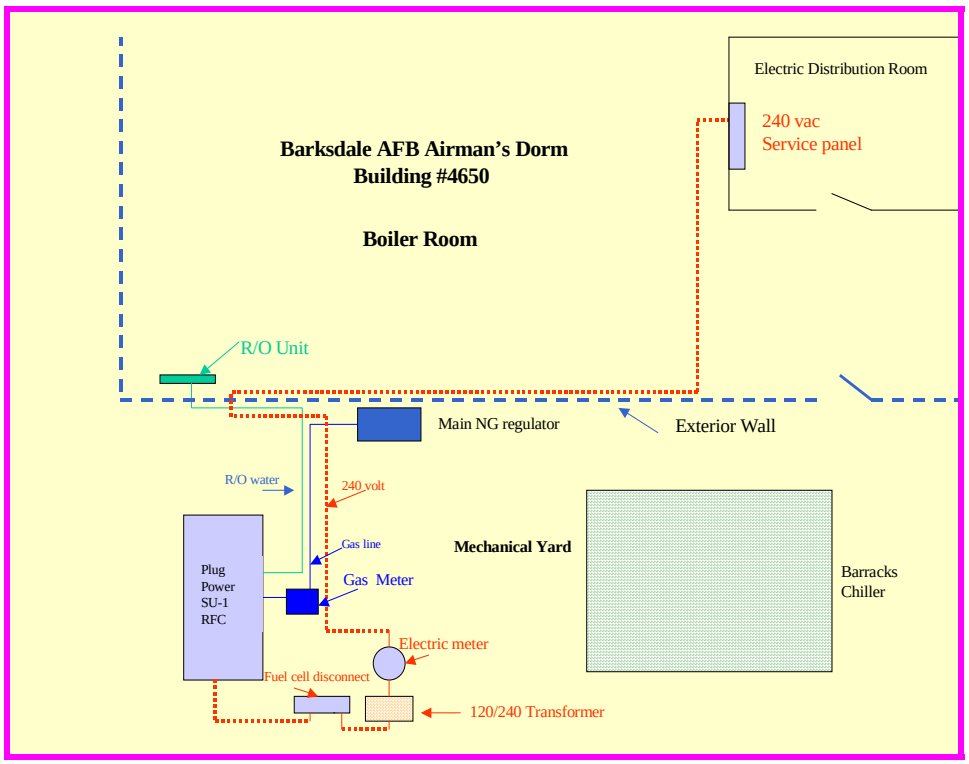

Figure 2 – PEM Fuel Cell Project one line "As Built" Drawing

A Reverse Osmosis water filtration system was installed in the boiler room to provide filtered process make-up water to the power plant. Make-up water was piped to the fuel cell as indicated in Figure 2, above, and the piping heat traced to prevent freezing.

9.0 Electrical System

The SU-1 inverter in the Barksdale fuel cell has a power output of 120 VAC at 60 Hz. However, the distribution panel in the mechanical room has connected loads at 240 VAC. In order to accommodate these loads, a 120/240 VAC step-up transformer was installed on the line between the fuel cell and the load panel. This is illustrated in the drawing pictured in Figure 2, which also traces the fuel cell conductor routing to the safety disconnect, then to the transformer, then to the meter and finally terminates at the 240vac service panel in the electric distribution room.

The photo in Figure 3 below shows the actual fuel cell electrical connection with the generator disconnect switch, transformer, and meter all mounted on the adjacent uni-strut rack.

Figure 3

The unit is configured for grid parallel service only, and the electrical conduit run is approximately 40 feet from the unit to the facility load panel.

10.0 Thermal Recovery

Not Applicable at this site.

11.0 Data Acquisition System

Over the course of developing the several sites in the FY01 PEM Program, LOGAN has encountered great difficulty in acquiring a dedicated phone line for the fuel cell at every site. In the best case this has delayed commencement of the period of performance by three weeks. At this site the base was unable to provide a discrete line to the fuel cell modem for nearly three months. In the end, LOGAN received permission to extend an existing line at the airman's dorm to the fuel cell modem to provide a data link with the factory. This is not the optimum solution, but it is an acceptable alternative for this installation since the line has very little other use at this time. These experiences have taught LOGAN to be very explicit with the host POC at the kick-off meetings about the necessity for providing a dedicated phone line since much of the success of the project is dependent upon reliable communications and data transmission with the unit.

During the period October 2002 to August 2003, LOGAN's field service technicians performed their tasks with the support of a very rudimentary SCADA system developed by Plug Power for communicating with deployed units. This system provided one-way communication from each unit to Plug's customer support center, allowing the unit to call in overnight to download a data package and an operating status report. However, LOGAN realized very quickly that the system was inadequate and unreliable to provide the high level of support needed for its wide-ranging PEM demonstration program. At times a unit called in and provided only partial data or incorrect data. This created uncertainty in troubleshooting and further delay in restoring units to service. On other occasions a unit might fail to call in for a week or more frustrating the normal chain of events leading to a service advisory. While Plug and LOGAN struggled initially with the learning curve experience in developing cooperative service norms, the weakness of the SCADA system became a major source of dissatisfaction with Plug Power. Under the circumstances the only means of determining a unit's actual status was to make a service call to the site. However, the scope of LOGAN's PEM program required a better solution. Finally, in March 2003 an event occurred that gave Plug direct insight into the shortcomings of its SCADA system. After advising of a shutdown at Fort Bragg, Plug sent its own technician to the site because LOGAN's technicians were servicing other units. The technician flew from Albany, NY to Raleigh, NC and then drove another two hours out to the site. Upon arriving, the technician discovered that the unit was operating normally. Indeed the SCADA system was not.

This event was an important turning point for the LOGAN/Plug Power relationship and it's cooperative efforts in pursuing the objectives of the PEM Demonstration Program. Six weeks later in early June, six representatives from LOGAN and eight from Plug Power met in Atlanta for two days of forthright discussions. The meeting focused on short-term methods and longer term solutions to improve remote PEM fuel cell performance. Most significantly Plug determined that it would institute immediate software changes and upgrades to insure the accuracy of fuel cell data communications. Following LOGAN's recommendations, Plug also promised to initiate a design change to its SCADA system that would permit bi-directional remote communications with the fuel cell controller. More importantly Plug promised that LOGAN's technicians would be able to remotely troubleshoot, change set points and attempt restarts under some circumstances. Lastly they also promised to publish a daily status report covering all of LOGAN's units. By early August Plug began sending daily status reports, and by mid September Plug shipped LOGAN new control software that permits remote diagnostics, monitoring, troubleshooting, and restart capabilities. Since the introduction of this new service capability along with the adoption of improved service techniques to go with it, fleet performance, availability and operating costs have begun to show positive new trends.

An external four-channel data-logger that shares the fuel cell phone line was installed to capture and store fuel cell kWh, ambient temperature, and natural gas usage. This data may be viewed at Appendix 1 below.

11.0 Fuel Supply System

The Plug Power fuel cell system is fueled by natural gas. The natural gas meter on the side of Building #4650 provides gas service as depicted in Figure 1. A regulator was installed at the fuel cell gas inlet to maintain the correct fuel inlet operating pressure of 10" water column.

The Plug Power PEM fuel cell natural gas requirements are:

- Must be >90% methane
- No greater than 15 ppm sulfur on a yearly average basis
- Supply Pressure: 4" to 11" water column

- Maximum flow rate: 105,000 btu/hr
- Nominal flow rate: 72,700 btu/hr

The natural gas supply flows from the utility meter on the exterior wall of Building #4650, to the new gas meter on the fuel cell as shown here.

12.0 Program Costs

Barksdale Air Force Base PEM Demonstration				
Project Utility Rates				
1) Water (per 1,000 gallons)		$ 1.50		
2) Utility (per KWH)		$ 0.017		
3) Natural Gas (per MCF)		$ 7.70		
First Cost			**Estimated**	**Actual**
Plug Power 5 kW GenSys5C			$ 42,500.00	$ 42,500.00
Shipping			$ 1,000.00	$ 1,800.00
Installation electrical			$ 2,200.00	$ 2,400.00
Installation mechanical & thermal			$ 2,400.00	$ 2,038.00
Watt Meter, Instrumentation, Web Package			$ 800.00	$ 680.00
Site Prep, labor materials			$ 925.00	$ 925.00
Technical Supervision/Start-up			$ 6,500.00	$ 15,300.00
Training			$ 5,000.00	$ 5,846.00
Total			**$ 61,325.00**	**$ 71,489.00**
Assume Five Year Simple Payback			$ 12,265.00	$ 14,297.80
Forcast Operating Expenses	Volume	$/Hr	$/ Yr	
Natural Gas Mcf/ hr @ 2.5kW	0.03	$ 0.25	$ 1,993.49	
Water Gallons per Year	14,016		$ 18.92	
Total Annual Operating Cost				$ 2,012.41
Economic Summary				
Forcast Annual kWH		19710		
Annual Cost of Operating Power Plant		$ 0.102	kWH	
Credit Annual Thermal Recovery		$ -	kWH	
Project Net Operating Cost		$ 0.102	kWH	
Displaced Utility cost		$ 0.017	kWH	
Energy Savings (Increase) (kWh)		($0.085)	kWH	
Annual Energy Savings (Increase)		($1,677.34)		

In the economic summary above the "Forecast Annual kWH" is based on an average fuel cell output setting of 2.5 kW's and 90% availability. Based on these assumptions the value of energy produced by the fuel cell will be $0.102 per kWH. The amount available for financing expressed as a credit to the project is ($0.0/kWh) the difference between the utility kWh rate ($0.017) and the fuel cell all-in operating cost per kWh ($0.102), indicating that there is no cash flow from the project to finance the installation costs. As the Annual Energy Savings calculation shows, the operation of the PEM fuel cell at Barksdale AFB had a negative impact ($1,677.34) upon the annual operating cost.

The Project Cost summary above is significantly affected by the very low cost of electricity and the fairly high cost of natural gas at Barksdale. Under these circumstances it can be seen that from an economic standpoint Barksdale AFB would be a very poor candidate for a residential PEM fuel cell. In order for PEM fuel cells to be an appropriate technology for Barksdale there would have to be benefits that outweigh the negative economic impact of the fuel cell. These benefits could arise from the utilization of the thermal output of the fuel cell, the ability of the fuel cell to operate during a power failure, or the environmental benefits derived from operating a low emissions fuel cell.

14.0 Milestones/Improvements

Between December 13, 2002 and March 5, 2004 two different PEM fuel cells were operated at building #4650 at Barksdale AFB. During this period there were 13 unplanned shutdown and zero planned shutdowns. Planned shutdowns were not needed because all Preventative Maintenance (PM) could be performed during one of the frequent unplanned outages. The 13 unplanned outages accounted for 4,300 hours of downtime – essentially the fuel cell was off more than it was on.

The complete replacement of the fuel cell in September, 2003 was a good faith effort to move the project closer to the goal of 90% availability. Unfortunately, both the original unit and the replacement were reconditioned equipment and neither proved up to the challenge.

Despite not achieving the performance goals, the PEM fuel cell demonstration at Barksdale AFB has resulted in a number of product/process improvements. The most noteworthy of which are:

- Distribution of spare part kits to LOGANEnergy field technicians which reduces “Mean Time to Repair” on each shutdown.
- Continued improvement in the communication between the customer support engineers at Plug Power and the LOGANEnergy technicians in the field.
- Increased knowledge of troubleshooting techniques and procedures on the part of both Plug Power support engineers and LOGAN technicians.
- The creation by Plug Power of a daily status report by email giving the condition of all fuel cells in the field.
- The distribution by Plug Power to the LOGAN technicians new control software that permits remote diagnostics, monitoring, troubleshooting, and restart capabilities.

15.0 Decommissioning/Removal/Site Restoration

The original PEM fuel cell installed at Barksdale was commissioned on February 28, 2003. The warranty on this fuel cell was scheduled to expire on February 27, 2004. Because of the very poor performance of this unit, the operation of this fuel cell was terminated on September 7, 2003 and subsequently replaced with another fuel cell. This new fuel cell was supposed to be a six month follow-up/extension. The new fuel cell was started on October 25, 2003 and was scheduled to terminate on April 24, 2004. Unfortunately, the second fuel cell installed at Barksdale performed as poorly as the first. On March 5, 2004 the fuel cell shutdown due to a Humidifier Level Low. This was the last shut down for this fuel cell. It was apparent to LOGANEnergy that the fuel cell would never be able to achieve the 90% availability benchmark and the unit was not restarted. The fuel cell was restarted on June 28, 2004 for one day in order to take harmonics readings and then was shut down permanently.

On June 29, 2004 all piping, conduit and wiring were disconnected from the fuel cell and all fuel cell related material and ancillary equipment were removed from the site. The fuel cell was shipped back to Plug Power on June 30, 2004.

16.0 Additional Research/Analysis

On June 28, 2004 a Harmonic Meter was used to measure the harmonics of the existing electrical system at the Environmental Center both with the fuel cell connected and with the fuel cell disconnected. The measurements from this test are attached in Appendix 3. (Harmonic readings are proprietary).

17.0 Conclusions/Summary

The Barksdale AFB PEM fuel cell demonstration consistently performed below expectations and failed the Program goal of 90% operational availability. LOGAN believes that the both reconditioned units provided for this site were ill suited for the task. The site work logs attached below as Appendix 2 chronicle 12 months of maximum effort in pursuit of this goal. Close scrutiny of the logs raises the notion that the chronic electrical and mechanical deficiencies uncovered in the unit are systemic and need correction at the factory level.

Without diminishing the Program's core value, it is important to recognize that something else very important has been taking place precisely because of the unit's unavailability. This project has exposed LOGAN, at once, to major field service tasks and overhauls, including rebuilding reformers, replacing cell stacks and rebuilding inverters; even to inventing new field modifications and service procedures to impress performance, while continuous troubleshooting episodes have covered every possible system deficiency. The learning curve experience that is occurring at this site normally requires years of field service exposure, and would not be a part of this discussion were this unit operating at 90%.

It is clear to LOGAN that what must be judged as this project's shortcomings in the strictest sense, the same is actually edifying to the broader Program objectives.

Appendix

1) Monthly Performance Data
2) Work Logs
3) Harmonic Meter Test Results
4) Installation Acceptance Test Log